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TITLE: PULSE-JET HELICOPTER POWER CONTROL SYSTEM DEVELOPMENT

PROGRESS REPORT FOR FOURTH THRU EIGHTH QUARTERS

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MODEL NO. CONTRACT NO. AF 33(600)-5860
Supplement No. 4 Items 1(d) and 1(

EXPENDITURE ORDER NO. I-506-230

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1. SUMMARY

Analysis, design, and fabrication of a programmed-throttle control system for a pulse-jet helicopter are completed. Flight tests are not within the scope of the present contract as amended. Cyclic fuel injection as a means for minimizing rotor shaking forces during forward flight is deemed not to offer improvements which would warrant the complexities involved.

2. INTRODUCTION

This progress report, which covers the fourth through the eighth quarterly periods, describes work performed under Items 1(d) and 1(e) of U. S. Air Force Contract No. AF 33(600)-5860 Supplement No. 4. These items cover the development of a basic power control system for pulse-jet powered helicopters and the investigation of cyclic fuel injection as a means of reducing rotor in-plane vibration and torque variation.

During the period, (15 April 1953 to 15 July 1954) covered by this report, the subject contract has been amended to reduce the scope of the power control items, with corresponding increases in emphasis being given to the development of pulse-jet engine components. Specifically, the ground and flight tests of the basic control system were deleted, as were design, fabrication and testing of the cyclic control system. Work on the remaining program has been carried out at low priority, with both expenditures and accomplishments during the past 15 months being approximately equivalent to that reported during each of the previous quarterly periods.

The first report of this series, Reference 1, contains a general discussion of possible power control configurations for pulse-jet helicopters without reference to a specific model. On the basis of that discussion, it is concluded that some form of programmed throttle actuation with collective pitch change (with the possible inclusion of a simple governor as a trimmer) is the most attractive possibility.

In the second report of the series, Reference 2, aerodynamic and power plant performance data for a typical pulse-jet propelled helicopter are presented and combined into level flight equilibrium charts. A fuel flow vs. collective pitch schedule is derived from these charts and a detailed fuel system is proposed to implement this schedule.

In the third report, Reference 3, fuel system response rates and rotor system inertia effects are presented for a typical pulse-jet helicopter. Calculations relating to a programmed-throttle type power control system are continued to cover steady-state operation over the entire helicopter flight range as well as dynamic performance during two typical maneuvers. The excellent results obtained with the programming control in these studies indicate the desirability of its continued development.

The present report describes additional evaluation of the programmed-throttle system including design, fabrication and limited bench testing of the actual components.

3. DISCUSSION

The following discussion is organized according to subject matter rather than according to quarterly period during which the work was accomplished. However, a chronological summary is presented in Table I which shows the distribution of work between the various periods.

3.1 Fuel System Response Rate

Calculations reported in Reference 2 indicate that the fuel system lag directly attributable to the cavitating-rotor type system of the XH-26 helicopter might be approximately 2.0 seconds. Tests on the XH-26, reported in Reference 3, show overall fuel system response times which are also about 1.5-2.0 seconds; however, the close correlation suggested by the numbers is not supported by study of the calculated and actual time histories. The calculated rotor fuel line response of Reference 2, Figure 12, indicates a rapid change of engine fuel flow immediately upon throttle movement, followed by an asymptotic approach to the final engine fuel flow. The actual time history of Reference 3 shows no appreciable change in engine fuel flow (noise level) for about 0.8 seconds following throttle movement, then the engine fuel flow changes rapidly, and finally approaches asymptotically to the final value. A probable explanation of the test data is as follows:

(a) There is a significant lag in the fuselage portion of the fuel system attributable to line stretch, relief valve inertia, etc. which may account for the first 0.8 second.

(b) The rotor fuel line lag is less than calculated, possibly because the 97% of final flow chosen as the cut-off point in Reference 2 takes in too much of the final asymptotic slope. For instance, the use of 92% of final flow as the end point would have led to a lag time of 1.0 second, instead of 2.0 second value previously quoted. This consideration is particularly valid for the case of increasing fuel flow, since as much as a ±10% change of fuel flow from the peak thrust value has a negligible effect on pulse-jet thrust.

Another series of tests similar to those of Reference 3 but with the addition of an instantaneous fuel pressure reading taken at the entrance to the rotary seal assembly would do much to clarify the fuel system lag picture. Such tests are recommended if the XH-26 flight schedule permits.

3.1.1 Rotor Fuel Line Lag

Two approaches to the reduction of lag in the present cavitating rotor fuel system were proposed in Reference 2 - (a) the reduction of rotor fuel line diameter near the tip, and (b) the use of a piston type "accelerator pump," which could best be tested in conjunction with the programmed-throttle control system. Neither of these schemes has been tested, and the current reduced budget for power control work will preclude such tests during the remainder of the program.

A third approach to this problem is the reduction of fuel injection pressure at the pulse-jet, with associated reduction of the fuel column length changes required for a given variation of fuel flow. To investigate this possibility, three means of reducing the pulse-jet fuel nozzle pressure drop have been tested.

3.1.1.1 Variable Orifice Fuel Nozzles

A pair of Lee Company, diaphragm-type, variable-area, "Dipole" fuel nozzles were purchased. One of these nozzles was installed in a 6.75" diameter pulse-jet and tested on the static thrust stand with results as shown in Figure 1. Significant reductions in fuel pressure were realized, but they were accompanied by a considerable reduction in peak thrust. The reduction in thrust is undoubtedly attributable to an inferior spray pattern which in turn is caused by a mismatch between the existing fuel baffle and the "Dipole" nozzle, which produces a hollow conical spray similar to that of the standard fixed nozzle but with a larger included angle such that the spray does not fully impinge on the baffle. Past experience has shown that optimizing the nozzle-baffle arrangement can be a tedious process and it was not undertaken in this case.

3.1.1.2 Forward Fuel Spray Bar

Work done under another contract included fabrication and testing of a fuel spray system located ahead of the pulse-jet valves, with static test results as summarized in Figure 1. Subsequent to these static tests, a similar system was whirl tested on 7.5" diameter, XH-26 engines with somewhat negative results from both engine performance and valve endurance standpoints. It is probable that this system can be perfected, but the effort required is beyond the scope of present programs.

3.1.1.3 High Capacity Fixed Orifice Fuel Nozzle

A fixed orifice nozzle rated 25 gph @ 100 psi instead of the standard 20 gph was tested during whirl tests of 7.5" diameter engines. No significant effects on peak thrust were noted; however, the lean blowout fuel flow was increased noticeably — an effect which has been found previously under similar circumstances. The use of 20 and 25 gph nozzles during the response rate tests mentioned in Section 3.1 might yield worthwhile data regarding the contribution of the rotor fuel line to the overall fuel system response rate.

3.2 Programmed Fuel Control System

Following receipt of approval from Wright Air Development Center early in the present report period, design and fabrication of the programmed throttle system was initiated. Details regarding the various components are outlined in the following paragraphs.

3.2.1 Additional Analysis

Dynamic performance calculations for the programmed throttle control installed in the XH-26 are reported fully in Reference 4 and are summarized in Reference 3. In both references, mention is made of the beneficial effect of large rotor inertia on transient rotor speed characteristics; however, the only quantitative results shown are in Figure 2 of Reference 3, which indicates the rate of change of rotor rpm for various pulse-jet thrust errors.

In order to further clarify this point, an additional transient response calculation for a horizontal pull-up has been performed corresponding to case 3 of the previous work (Figure 4, Reference 3 or Figure 12, Reference 4) except that rotor polar inertia has been reduced from the XH-26 value of 450 slug-feet^2 to a value of 100 slug-feet^2 which is representative of a shaft driven helicopter of similar gross weight. The results of this study are included as Figure 2, which shows that with the XH-26 rotor inertia, the maximum rotor overspeed is 10.5% and occurs 8 seconds after the start of the maneuver; whereas for the smaller rotor inertia, the maximum overspeed is 18% and occurs less than 0.6 seconds after the start of the maneuver.

Since ±10% rotor speed variations are tolerable, the larger rotor inertia makes the difference between an acceptable and an unacceptable control system. These results bear out the statements on page 7 of Reference 4 which are quoted below:

"The programmed throttle has been in use for some time on reciprocating engine helicopters, but has not been successful in making these helicopters essentially "one control" (i.e., collective pitch control) machines because the trim changes required to keep the rotor speed within limits must be made about as quickly as the throttle changes required with no program. Thus, about all that has been accomplished has been to reduce the amount of coordinated throttle movement required for a given change in collective pitch. The large inertia of the pulse-jet helicopter rotor and its relatively short fuel system time lag suggest, however, that a programmed throttle control by itself, even without trim control from the pilot, might keep the rotor speed sufficiently close to a mean operating speed so that the system could be considered a rotor speed governing power control system. This consideration prompted the investigation in this report."

3.2.2 Design and Fabrication of Programmed Throttle

The goal of this design program was the achievement of a simple, reliable linkage involving minimum changes from existing XH-26 hardware. The degree of success may be partially judged from the "before-and-after" photographs of Figure 3. The XH-26 dual throttle assembly was cut in half, with the aft unit remaining in place as the manual override bypass valve of Figure 10, Reference 2. The small twist grip and cam drive for this valve are also used without change. The forward throttle unit has been relocated in the auxiliary linkage box which mounts on the cockpit floor beside the collective pitch stick as shown in Figure 3. This valve becomes the programmed throttle and is actuated by the cam and linkage of the auxiliary box; these units, in turn, are actuated by the main pivot shaft of the collective pitch arm (not included in photograph). The main twist grip on the collective pitch lever is connected through a system of levers to the main pivot shaft so that rotation of the grip produces the same effect on the programmed throttle as does a change of collective pitch. This action provides the pilot's primary trim control and is illustrated schematically as a cam shift in Figure 10 of Reference 2.

Calculated cam characteristics for the XH-26, for example Figure 3 of Reference 3, indicate that pulse-jet rich and lean limit fuel flows will be reached well within allowable collective pitch travel; therefore, the equivalent of a large flat region must be provided at each end of the cam to allow for overtravel. During the detail design of the linkage, it became apparent that such a large cam travel is not feasible because of cam clearance problems as

well as angular travel limitations in the multiplying linkage. A unique spring overtravel unit was developed as an alternative and has been demonstrated to be both accurate and dependable. It offers positive positioning through the cam operating range, coupled with adequate overtravel to accommodate a simultaneous application of full collective pitch plus full trim adjustment. Sufficient trim is available to obtain lean limit fuel flow with a collective pitch which would normally call for maximum fuel flow and vice versa. Such a drastic trim change might be used if the pilot desires to change his rotor speed in anticipation of the requirements of a violent maneuver such as a jump take-off or a horizontal pull-up.

3.2.3 Determination of the Cam Contour

The first step toward determination of the cam contour is the calculation of the required engine fuel flow vs. collective pitch relationship as described in Reference 4. The curves which have been obtained are based on obsolete engine performance data and will need to be modified in the event that a flight test program is reinstated.

The second step is to define the relative motion of the collective pitch lever and the cam. This can be done readily by means of layouts or by means of actual measurements on the hardware.

The third step is to obtain the fuel flow vs. displacement characteristics of the valve. Tests for this purpose have been performed with results as shown in Figure 4. The throttle pressure drop of 30 psi used in these tests is as large as can be provided on the XH-26 without exceeding the allowable fuel pump working pressure. Curves are shown for the standard seat diameter of .0935 inch and for an enlarged seat of 0.101 inch which is required to provide adequate fuel flow without encountering the erratic behavior as the shoulder of the needle passes the seat.

The fourth and final step is the combination of the above information with a profile of cam radius vs. angle.

3.2.4 Altitude Compensator

The altitude compensator shown in Figure 5 has been developed under a subcontract by the Lee Company of Westbrook, Connecticut. This unit was built to the requirements of Reference 5 with minor amendments as agreed to by this contractor and the subcontractor. These amendments are as follows:

Section 4.3.1: equation should read $\Delta P = K(P_a)^2$

Section 4.3.7: bleed flow shall not exceed 40 lb/hr at sea level

no section number: unit shall be capable of bypassing an excess fuel pump output of 1000 lb/hr (AHCo letter 53-1599)

The unit was tested at the Lee Company prior to delivery as reported in Reference 6, which also contains schematic and assembly drawings. Performance of the compensator is apparently satisfactory, and it is available for use if a flight test program becomes possible at a later date.

3.2.5 Alternative Test Program

As a possible alternative to the originally planned flight tests which were primarily delayed because of unavailability of a suitable XH-26 helicopter, a combination hardware-analogue study was proposed. This scheme involved use of the previously described programmed throttle hardware connected to the fuel flow bench and interrelated with an analogue computer set-up to simulate the flight characteristics of the XH-26. Similar programs have been performed, and the project appeared technically feasible; however practical considerations, including finances, led to termination at the proposal stage.

3.3 "Fully Automatic" Control System

The programmed throttle control system was selected for fabrication and testing on the XH-26 because of its simplicity, stability, and apparently adequate accuracy. However, since a more elaborate system might be desirable for some subsequent pulse-jet helicopter, a requirement was established for a control system which requires a minimum amount of pilot attention regardless of the complexity involved. For convenience, this "fully automatic" system has been considered as two separate problems: (a) governed throttle, and (b) automatic start sequencing.

3.3.1 Governed Throttle System

As a result of several discussions between WADC personnel and employees of this contractor, it was decided that the consideration of automatic rotor speed governing should be subcontracted to an organization specializing in control work. Accordingly, proposals were solicited from four such concerns, and two excellent proposals were received. These proposals were forwarded to WADC as enclosures to Reference 7, and approval was requested for issuance of a subcontract

to the Sperry Gyroscope Company, whose proposal was deemed most acceptable. During the course of these negotiations, the previously mentioned contractual changes were effected, and the reduced funds prohibited continuation of this work.

As is discussed on pages 7 through 9 of Reference (1), full advantage cannot be taken of the pulse-jet helicopter's inherent maneuverability unless the pilot is able to utilize the rotational inertia of the rotor system. During such maneuvers, the power plants are not capable of maintaining constant rotor speed, and the pilot will have to monitor the rpm. It has been suggested that warning lights or other signals be provided to warn the pilot before dangerous speed errors are encountered so that he can take corrective action. The use of automatic collective pitch limiting devices to prevent dangerous speed errors have also been considered, but the questionable value of such devices does not appear to warrant the complexity involved. Since even the governed throttle system leaves rpm monitoring responsibility with the pilot during many exacting maneuvers, and in view of the excellent behavior shown for the programmed throttle system, it is considered that termination of governed throttle studies does not represent a serious reduction of the overall program.

3.3.2 Automatic Start Sequencing

Experience with turbojet and ramjet power plants has shown that both require prompt and accurate throttle control during starting and acceleration procedures. Based upon this experience, WADC personnel raised logical questions regarding similar procedures for pulse-jet helicopters and suggested that a "fully-automatic" control system might reduce the requirements placed on pilot skill by providing automatic sequencing of fuel, air, and spark during the starting and acceleration cycle.

3.3.2.1 Acceleration Procedure

This contractor's experience with pulse-jet helicopters has shown that, once started, the engines typically exhibit wide fuel flow operating limits over the entire speed range from static to maximum overspeed. In fact, for the XH-26, it is doubtful if the engines can be made to blow out, either rich or lean, during the acceleration period without forcing the throttles beyond their rich or lean limit stops. It appears, therefore, that automatic control during the acceleration procedure can be eliminated from further consideration.

2.3.2.2 Starting Procedure

Flight test experience with the XH-26 helicopter pointed out a starting problem as follows:

(a) The time required for fuel to reach the engine after throttle opening depended upon the amount of fuel initially present in the lines downstream of the throttle and varied from zero to about seven seconds.

(b) If fuel was allowed to accumulate in the engine prior to the introduction of compressed air through the air start manifold, a fire was likely to occur. The compressed air would not purge the engine so that a start was not possible; and also, the valves were frequently damaged by heat.

(c) If air was introduced immediately upon throttle opening and the fuel delay was maximum, the compressed air supply might be inadequate.

As a result of this problem, considerable thought has been given various means of coordinating the introduction of fuel and air into the engine. The simplest and most promising expedient appeared to be the addition of a spring loaded fuel shut-off valve at the rotor tip which would insure a full fuel line to that point and would provide immediate response to both air and fuel valve operation in the cockpit.

Meanwhile, development of an improved air start system was carried on under another contract, with excellent results as reported in Reference 8. An air start manifold located ahead of the engine inlet valves was found to be superior to the previous manifold which was located aft of the valves. Using XH-26 components throughout, immediate starts were obtained even after the engine had been flooded for 10 seconds. The compressed air supply was found to be adequate for 6 starts (it is recharged during flight, so only one start is required), and no valve burning was evidenced.

With both starting and acceleration reduced to virtually fool-proof procedures, it is considered that no further effort is justified on starting and acceleration under the present contract.

3.4 Cyclic Fuel Injection

Work under this item is intended to: (a) determine the extent of rotor shaking force and torque variation associated with constant pulse-jet fuel flow during forward flight, and (b) investigate feasibility of, and techniques for, minimizing these effects through cyclic fuel injection.

3.4.1 Variation of Thrust with Yaw Angle and Forward Speed

Since the effect of forward speed on pulse-jet thrust has been defined by tests performed for other purposes, only the effect of yaw angle was determined specifically for this study. A special engine attachment fitting was built to allow either pitch or yaw settings to be varied with the engine attached to the blade tip of a whirl test stand, and data were taken over the full range of adjustment.

The data showed unexpected differences between positive and negative yaw settings, and careful study of the results indicated that interference effects between the engine and the attach fitting may have been responsible. Furthermore, the task of providing a yaw fitting which would be above question was beyond the scope of this work. The data also added substantiation to the hypothesis that yaw and pitch should have similar effects on engine thrust. Fortunately, the variation of pitch alone can be accomplished without special fittings since the engines are normally pitch swivelled, and the swivel can be locked during whirl stand testing. Pitch data taken by means of this technique, which became available from power plant development tests, were studied in conjunction with the data from this program; and the yaw effect curves of Figure 6 were synthesized for use during the present study. The effects of yaw are of considerable importance to the overall performance of a pulse-jet helicopter; therefore, they are recommended for more extensive study as part of the overall power plant development program.

3.4.2 Response to Cyclic Fuel Injection

No information regarding the transient response characteristics of pulse-jet engines existed at the beginning of this program, so the present work represents a considerable venture into unexplored terrain. Typical problems were the design of a fuel injection system capable of flow modulation of frequencies up to 10 cycles per second and the development of a test stand with instrumentation for measuring small thrust increments and phase shifts at 10 cps in the presence of very large thrust variations at the engine firing frequency of 125 cps.

Because various aspects of this work may be of value in other fields, a rather complete report is being published, Reference 9. The results obtained are still subject to certain questions, but they appear to be entirely adequate for present purposes. An example of a result which may shed light on the basic operation of pulse-jet engines is the phase shift curve of Figure 7. It is interesting to note that all the data points lie close to the 1/60 second lag line and that the engine pulsing cycle requires about 1/120 second. This result indicates that the pulse-jet can adjust its operation to a new fuel flow within two pulsing cycles.

Other conclusions of this work are that, within the range of frequency explored, the amplitude of thrust variation and the mean specific fuel consumption are little affected by cyclic injection frequency.

3.4.3 Analysis of Effects on the Helicopter

The report covering the analysis of cyclic pulse-jet thrust effects on the helicopter is being published, Reference 10. In general, it is found that cyclic fuel injection could be used to reduce torque variations and shaking forces during forward flight, but that the initially small values of these oscillating forces are not sufficient to justify the considerable complexity involved.

It is also pointed out in this report that average pulse-jet thrust is materially reduced during forward flight, due primarily to yaw effects, and that this reduction of thrust (rather than blade stall considerations) may limit the maximum flight speed of the helicopter. Cyclic fuel injection could be utilized to offset a small part of this thrust decline, but again the improvement appears not to warrant the complexity. Incidentally, the cyclic fuel injection schedule for thrust improvement is not the same as the one for shaking force improvement.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Programmed Throttle

The analysis, design, and fabrication phases of the programmed throttle control development are considered to be complete. As a result of contract changes, no further work is planned. The system is ready for installation and is recommended for flight testing if service experience with the XH-26 helicopters indicates the desirability of a semi-automatic throttle control.

4.2 Cyclic Fuel Injection

Publication of References 9 and 10 will complete work under this phase as amended. Results of the study lead to the recommendation that no further consideration of cyclic fuel injection be planned unless some future pulse-jet helicopter should disclose unexpectedly adverse flight characteristics.

4.3 Other Recommendations

Additional fuel system response measurements on the XH-26 are recommended to further define the fuselage fuel system and rotor fuel line contributions to the overall lag time.

Yaw and pitch effects on pulse-jet thrust are recommended for added study under power plant development programs.

5. REFERENCES

Reference 1: American Helicopter Co., Inc. Report No. 195-A, "Pulse-Jet Helicopter Power Control System Development - First Quarterly Progress Report", R. W. McJones, 1 February 1953.

Reference 2: American Helicopter Co., Inc. Report No. 195-B, "Pulse-Jet Helicopter Power Control System Development - Second Quarterly Progress Report", R. W. McJones, 1 March 1953.

Reference 3: American Helicopter Co., Inc. Report No. 195-C, "Pulse-Jet Helicopter Power Control System Development - Third Quarterly Progress Report", R. W. McJones, 24 April 1953.

Reference 4: American Helicopter Co., Inc. Report No. 195-C-1, "Analysis of a Programmed Throttle Power Control System for a Typical Pulse-Jet Helicopter", L. R. Gutstadt, 15 June 1953.

Reference 5: American Helicopter Co., Inc. Report No. S-195-a, "Specification for Altitude Compensators for Pulse-Jet Helicopter Fuel Systems", R. W. McJones, 15 June 1953.

Reference 6: The Lee Company, "Report on Test Results of Altitude Compensator" (Drawing No. 11,000), J. F. Somers, 19 March 1954

Reference 7: American Helicopter Co., Inc., Letter No. 53-2013, to Wright Air Development Center, WCLPN-2, Subject: "Proposed Subcontract to Sperry Gyroscope Company."

Reference 8: American Helicopter Division of Fairchild Engine and Airplane Corporation, IOM No. 0482 "Results of Forward Air Start System Development" D. S. Perkins, 23 June 1954. (To be reported formally.)

Reference 9: American Helicopter Division of Fairchild Engine and Airplane Corporation, Report No. 195-G-1, "Effects of Low-Frequency Cyclic Fuel Injection on the Static Performance of a Pulse-Jet Engine," C. H. Thomas, to be published.

Reference 10: American Helicopter Division of Fairchild Engine and Airplane Corporation, Report No. 195-H-1, "Analysis of Cyclic Fuel Injection as a Means of Improving the Forward Flight Characteristics of a Pulse-Jet Helicopter", R. H. Spidell, to be published.

TABLE I

CHRONOLOGICAL SUMMARY BY QUARTERS

Fourth Quarter - 195-D

Received proposals for subcontract study of "Fully Automatic" Control System.

Initiated analysis of cyclic fuel injection.

Completed yaw and pitch whirl tests for cyclic injection program.

Received WADC approval to proceed with programmed throttle design and fabrication.

Transmitted report on programmed throttle system, Reference 4.

Fifth Quarter - 195-E

Initiated design and fabrication, programmed throttle hardware.

Conducted bench tests of throttle components.

Issued purchase order to Lee Company for altitude compensator.

Conducted preliminary cyclic fuel injection tests on static stand - found hardware inadequate and instituted redesign.

Sixth Quarter - 195-F

Completed fabrication of programmed throttle hardware.

Fabricated new hardware for cyclic fuel tests.

Considered combination analogue-hardware tests of programmed throttle system.

Requested WADC approval of Sperry subcontract.

Completed cyclic fuel tests on static stand.

Performed additional XH-26 rotor inertia effect calculations (Figure 2).

TABLE I - Continued

Seventh Quarter - 195-G

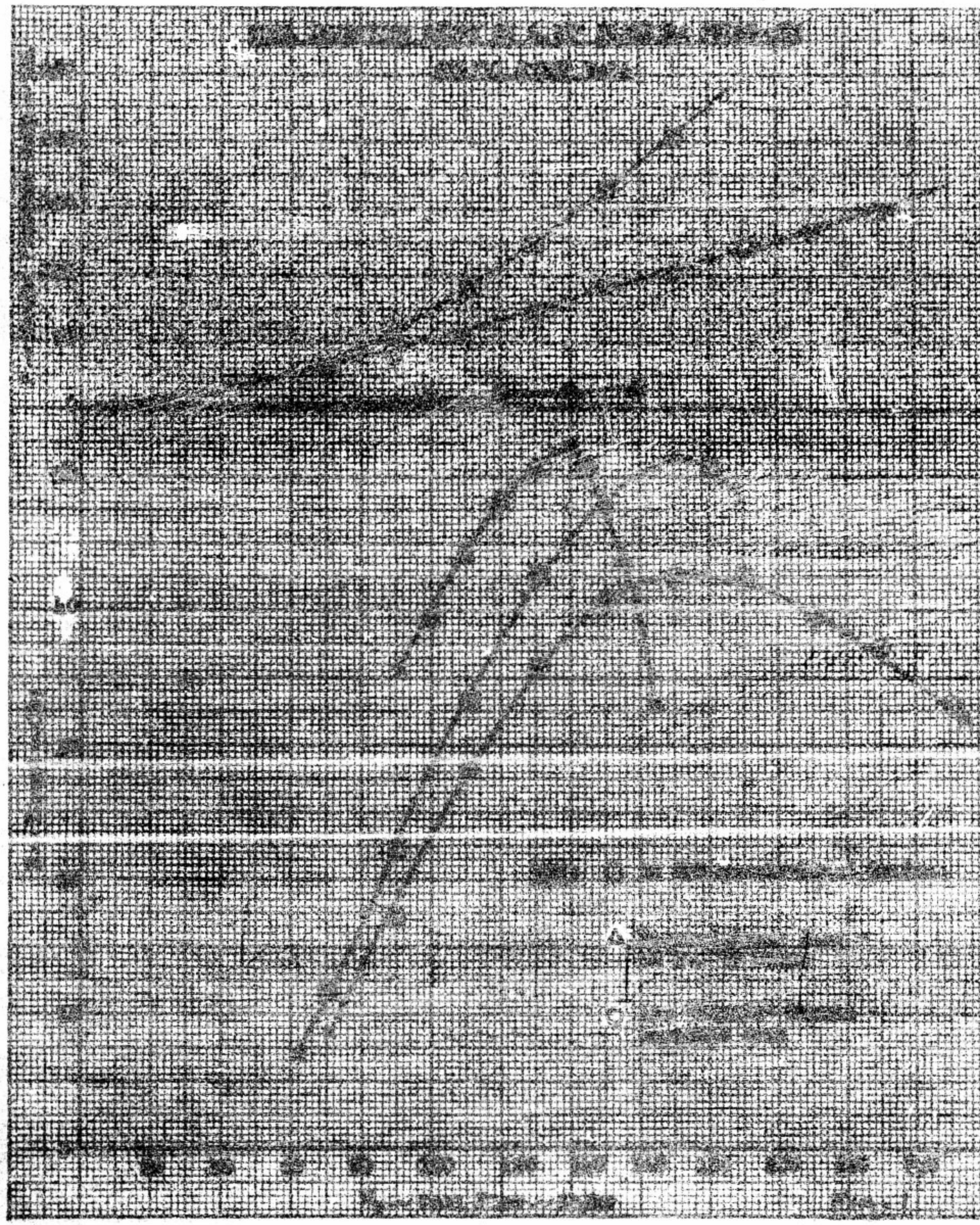
Received altitude compensator from Lee Company

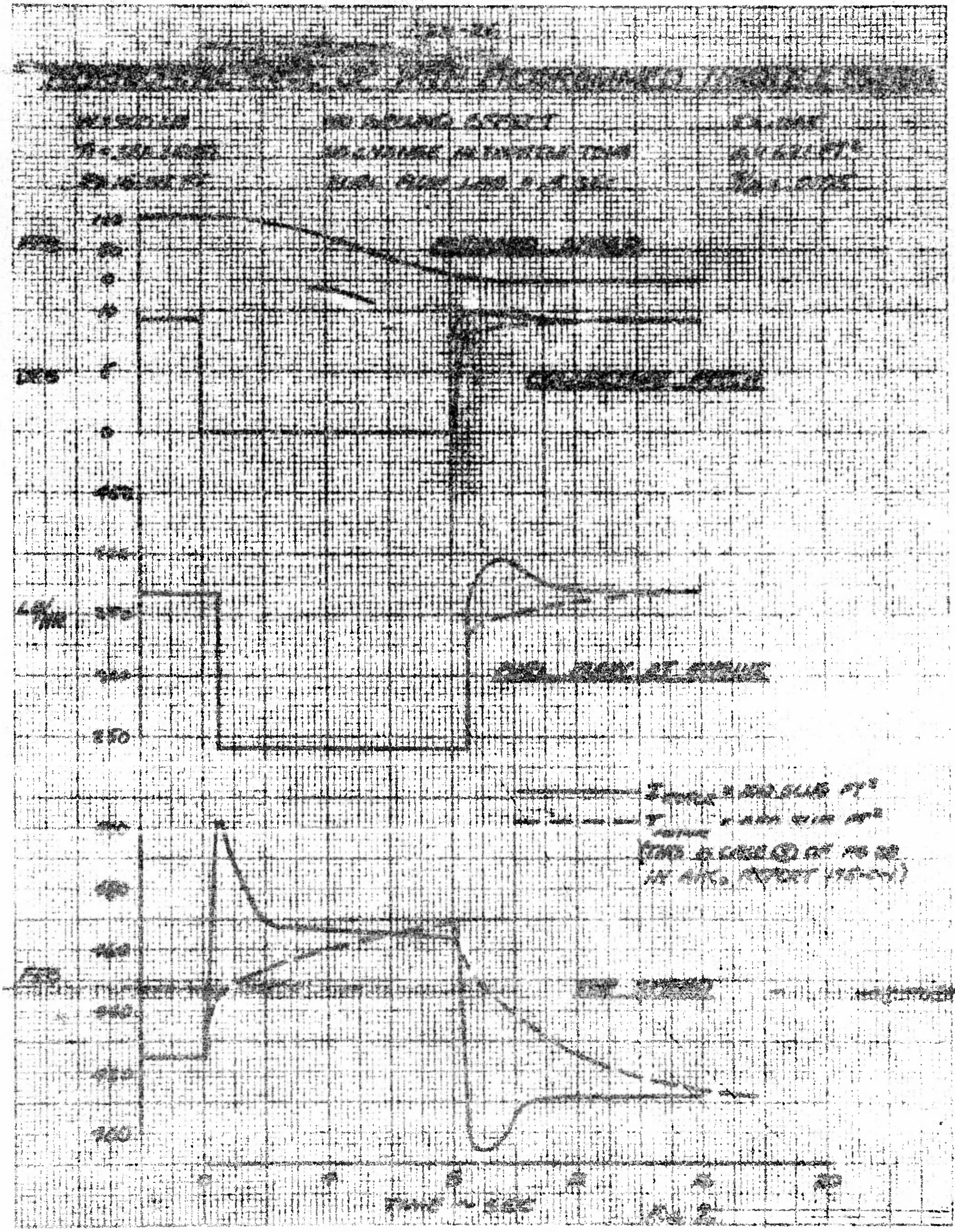
Tested low pressure drop fuel nozzles in pulse-jet engines.

Eighth Quarter - 195-H

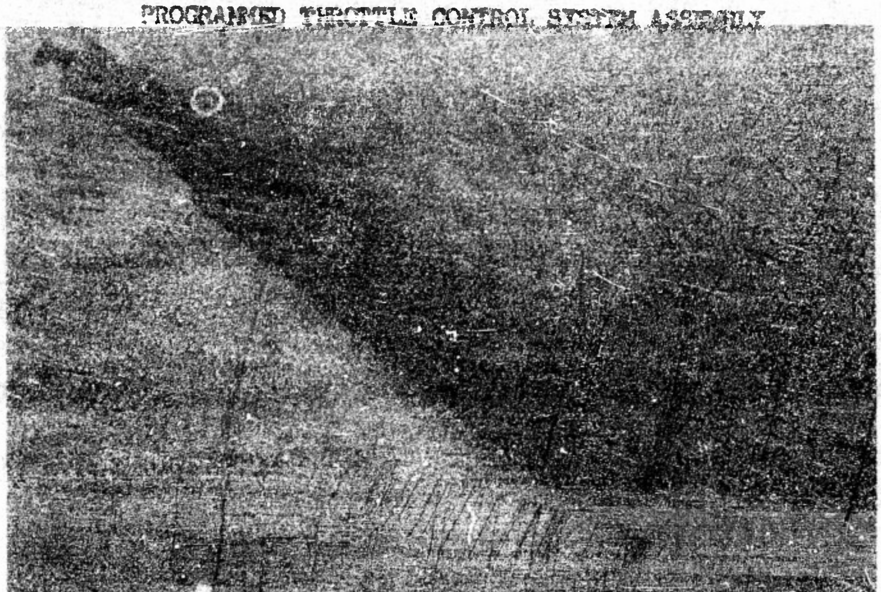
Completed Analysis of Cyclic Fuel Injection, Reference 10.

Completed Report on Cyclic Fuel Tests, Reference 9.

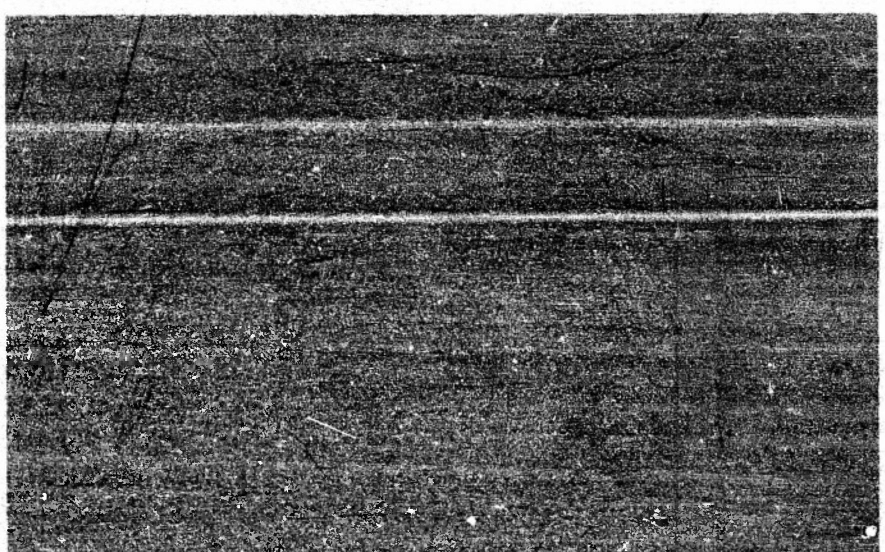




PROGRAMMED THROTTLE CONTROL SYSTEM ASSEMBLY

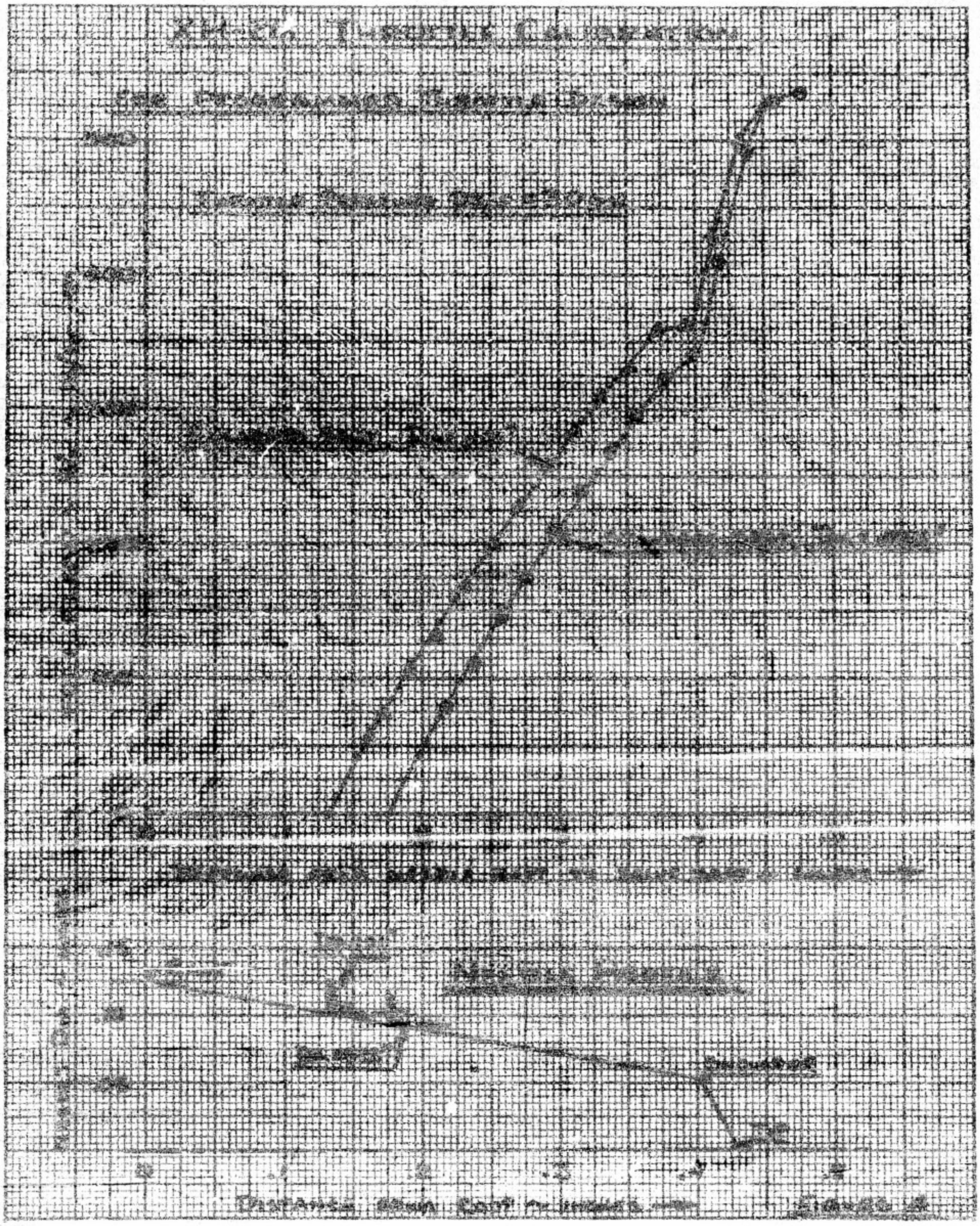


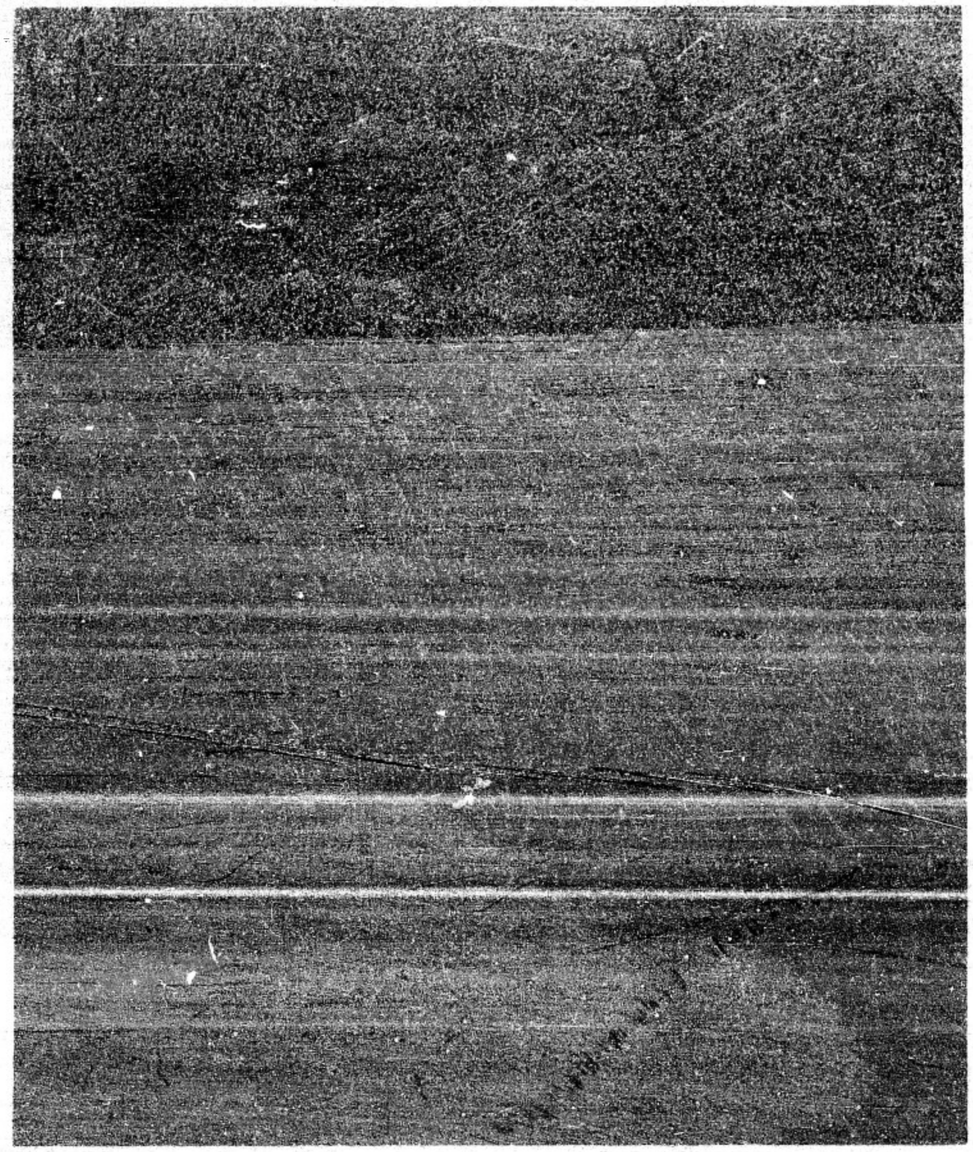
XH-26 COLLECTIVE PITCH - THROTTLE ASSEMBLY BEFORE MODIFICATION



ASSEMBLY MODIFIED FOR PROGRAMMED CONTROL OF THROTTLE

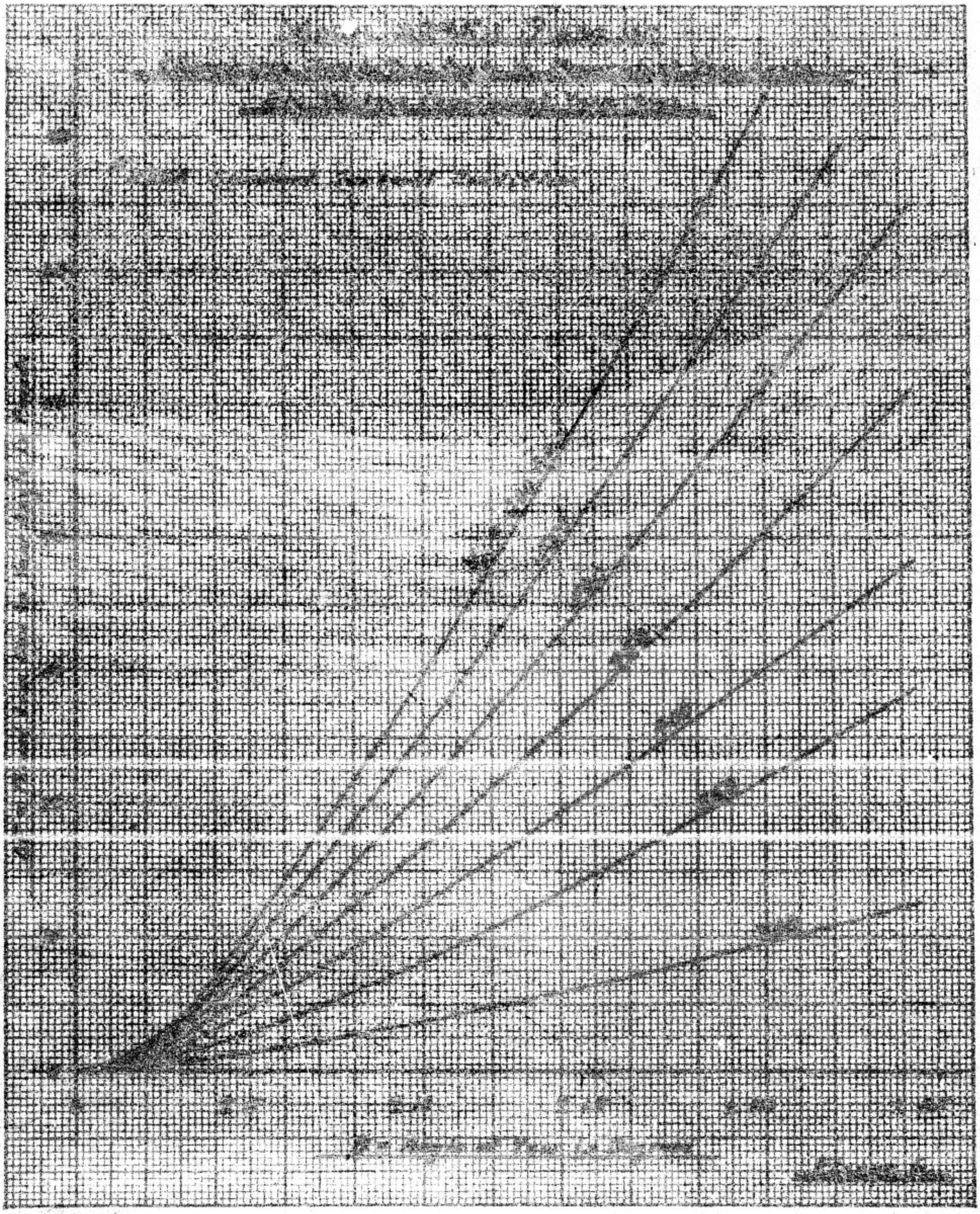
FIGURE 3

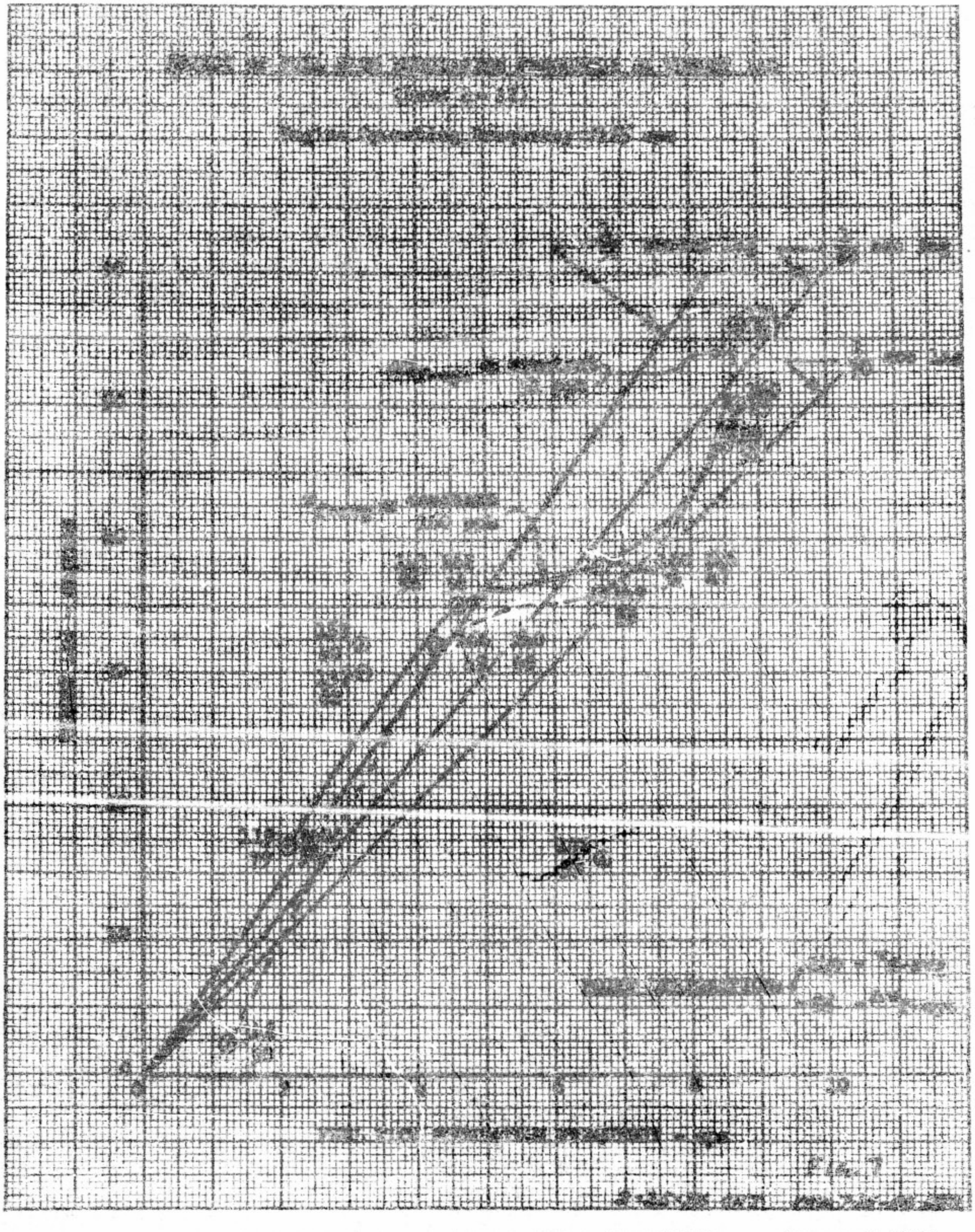




ALTITUDE COMPENSATOR

FIGURE 5





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